CLAIMS:

1. An optical system for *in vivo*, non-invasive transcranial examination of brain tissue of a subject comprising:

an optical module including an array of optical input ports and detection ports located in a selected geometrical pattern to provide a multiplicity of photon migration paths inside an examined region of the biological tissue, each said optical input port being constructed to introduce visible or infrared light emitted from a light source, each said optical detection port being constructed to receive photons of light that have migrated in the examined tissue region from at least one of said input ports and provide said received light to a light detector;

a controller constructed and arranged to control operation of said light source and said light detector to detect light that has migrated over at least one of said photon migration paths; and

a processor connected to receive signals from said detector and arranged to form at least two data sets, a first of said data sets representing blood volume in the examined tissue region and a second of said data sets representing blood oxygenation in the examined tissue region; said processor being arranged to correlate said first and second data sets to detect abnormal tissue in the examined tissue region.

2. The optical system of claim 1 wherein said second data set includes hemoglobin deoxygenation values.

3. The optical system of claim 1 wherein said processor is arranged to form a third data set being collected by irradiating a reference tissue region.

4. An optical system for *in vivo*, non-invasive transcranial examination of brain tissue of a subject comprising:

an optical module including an array of optical input ports and detection ports located in a selected geometrical pattern to provide a multiplicity of photon migration paths inside an examined region of the biological tissue, each said optical input port being constructed to introduce visible or infrared light emitted from a light source, each said optical detection port being constructed to receive photons of light that have migrated in the tissue from at least one

of said input ports and provide said received light to a light detector;

a controller constructed and arranged to control operation of said light source and said light detector to detect light that has migrated over at least one of said photon migration paths; and

a processor connected to receive signals from said detector and arranged to form at least two data sets, a first of said data sets being collected by irradiating an examined tissue region of interest and a second of said data sets being collected by irradiating a reference tissue region having similar light scattering and absorptive properties as the examined tissue region, said processor being arranged to correlate said first and second data sets to detect abnormal tissue in the examined tissue region.

5. An optical system for *in vivo*, non-invasive transcranial examination of brain tissue of a subject comprising:

an optical module including an array of optical input ports and detection ports located in a selected geometrical pattern to provide a multiplicity of photon migration paths inside an examined region of the biological tissue or a model representing biological tissue, each said optical input port being constructed to introduce visible or infrared light emitted from a light source, each said optical detection port being constructed to receive photons of light that have migrated in the tissue or the model from at least one of said input ports and provide said received light to a light detector;

a controller constructed and arranged to control operation of said light source and said light detector to detect light that has migrated over at least one of said photon migration paths; and

a processor connected to receive signals from said detector and arranged to form at least two data sets of two tissue regions, a first of said data sets being collected by irradiating an examined tissue region and a second of said data sets being collected by irradiating a region of a tissue model having selected light scattering and absorptive properties, said processor being arranged to correlate said first and second data sets to detect abnormal tissue in the examined tissue region.

6. The optical system of claim 1 or 3 further including a second optical module

including an array of optical input ports and detection ports located in a selected geometrical pattern to provide a multiplicity of photon migration paths inside an examined region of the tissue, each said optical input port being constructed to introduce visible or infrared light emitted from a light source, each said optical detection port being constructed to receive photons of light that have migrated in the examined tissue region from at least one of said input ports and provide said received light to a light detector; said processor being arranged to receive optical data from both said optical modules.

7. The optical system of claim 1, 4 or 5 wherein said processor is arranged to correlate said first and second data sets by determining congruence between data of said two sets.

8. The optical system of claim 7 wherein said processor is programmed to order said first and second data sets as two-dimensional images and to determine said congruence using said two-dimensional images.

9. The optical system of claim 7 wherein said processor is programmed to order said first and second data sets as two-dimensional images and to determine said congruence using the following formula:

$$1-\left(\frac{maximum\ \ overlap\ \ residual}{maximum\ \ selected\ \ tissue\ \ signal}\right)\times 100$$

10. The optical system of claim 1, 2, 3, 4, 5, 6, 7, 8 or 9 wherein said processor is further arranged to determine a location of said abnormal tissue within the examined tissue region.

11. The optical system of claim 1, 4 or 5 wherein said processor is adapted to produce from said data set an image data set by implementing an optical tomography algorithm.

12. The optical system of claim 11 in which said optical tomography algorithm employs factors related to determined probability distribution of photons attributable to the scattering character of the tissue being imaged.

13. The optical system of claim 1, 4 or 5 wherein said controller is arranged to activate said source and said detector to obtain a first selected distance between said input and detection ports and said processor is arranged to form said data set for said first distance.

14. The optical system of claim 13 wherein said processor produces an image data set from said data set formed for said first distance.

15. The optical system of claim 13 wherein said controller further is arranged to activate said source and said detector to obtain second distance between said input and detection ports and said processor is arranged to form another data set for said second distance.

16. The optical system of claim 11, 12, 13, 14 or 15 further including a display device constructed to receive said image data set from said processor and to display an image.

17. The optical system of claim 1, 4 or 5 further comprising

a first oscillator constructed to generate a first carrier waveform at a first frequency on the order of 10^8Hz, said first frequency having a time characteristic compatible with the time delay of photon migration from said input port to said detection port;

said light source being coupled to said first oscillator and constructed to generate said light modulated by said first carrier waveform;

a phase detector constructed to determine change in waveform of the detected light relative to the waveform of the introduced light and measure therefrom the phase shift of said detected light at said wavelength, said phase-shifted light being indicative of scattering or absorptive properties of the examined tissue region; and

said processor being arranged to form said data set based on the measured phase shift.

18. The optical system of claim 17 further comprising

a second oscillator constructed to generate a second waveform at a second frequency;

said detector being arranged to receive a reference waveform at a reference frequency offset by a frequency on the order of 10^3Hz from said first frequency and to produce a signal, at said offset frequency, corresponding to said detected radiation; and

said phase detector being adapted to compare, at said offset frequency, the detected radiation with the introduced radiation and to determine therefrom said phase shift.

19. The optical system of claim 1, 4 or 5 further comprising:

an oscillator constructed to generate a first carrier waveform of a selected frequency compatible with time delay of photon migration from said input port to said detection port; said light source being connected to receive from said oscillator said carrier waveform and constructed to generate optical radiation modulated at said frequency;

a phase splitter connected to receive said carrier waveform from said oscillator and produce first and second reference phase signals of predefined substantially different phases;

first and second double balanced mixers connected to receive from said phase splitter said first and second reference phase signals, respectively, and connected to receive from said detector said detector signal and to produce therefrom a in-phase output signal and a quadrature output signal, respectively; and

said processor being connected to said double balanced mixers and arranged to receive said in-phase output signal and said quadrature output signal and form therefrom said data set.

20. The optical system of claim 19 wherein said processor is arranged to calculate a phase shift (Θ_λ) between said light introduced at said input port and said light detected at said detection port prior to forming said data set.

21. The optical system of claim 19 wherein said processor is arranged to calculate an average migration pathlength of photons scattered in the examined tissue between said optical input port and said optical detection port prior to forming said data set.

22. The optical system of claim 21 wherein said processor further employs said pathlength in quantifying hemoglobin saturation (Y) of the examined tissue.

23. The optical system of claim 19 wherein said processor is arranged to calculate a signal amplitude (A_λ) determined as a square root of a sum of squares of said in-phase output signal and said quadrature output signal prior to forming said data set.

24. The optical system of claim 23 further comprising:

a narrow band detector connected to receive from said optical detector said detector signal and to produce a DC output signal therefrom; and

said signal processor further determining a modulation index (M_λ) as a ratio of values of said signal amplitude and said signal amplitude plus said DC output signal.

25. The optical system of claim 1, 4 or 5 further comprising:

at least one oscillator constructed to generate a carrier waveform of a selected frequency, said light source being operatively connected to said oscillator constructed to generate light of a visible or infrared wavelength, said light being intensity modulated at said frequency to achieve a known light pattern;

said controller constructed to control the emitted light intensity or phase relationship of patterns simultaneously introduced from multiple input ports, said introduced patterns

forming resulting radiation that possesses a substantial gradient of photon density in at least one direction, said resulting radiation being scattered and absorbed over said migration paths;

said detector constructed and arranged to detect over time the resulting radiation that has migrated in the tissue to said detection port, and

said processor being further arranged to process signals of said detected resulting radiation in relation to said introduced radiation to create said data sets indicative of influence of the examined tissue upon said substantial gradient of photon density of said resulting radiation.

26. The optical system of claim 25 further comprising a phase detector constructed to detect the phase of the detected radiation and provide said phase to said processor.

27. The optical system of claim 25 further comprising an amplitude detector constructed to detect the amplitude of the detected radiation and provide said amplitude to said processor.

28. The optical system of claim 25 wherein the phase relationship of light patterns introduced from two input ports is 180 degrees.

29. The optical system of claim 1, 4 or 5 wherein said light source produces relatively long light pulses and the processor forms said data set by subtracting amplitude of two said pulses emitted from two input ports located symmetrically relative to one detection port.

30. The optical system of claim 1, 4 or 5 constructed to introduce and detect photons at two wavelengths selected to provide sensitivity to a tissue constituent.

31. The optical system of claim 30 wherein said tissue constituent is an endogenous pigment.

32. The optical system of claim 31 wherein said endogenous pigment is hemoglobin.

33. The optical system of claim 30 wherein said tissue constituent in an exogenous pigment.

34. The optical system of claim 33 in which said exogenous pigment is a selected contrast agent.

35. An optical method for *in vivo*, non-invasive transcranial examination of brain tissue of a subject comprising:

providing an optical module including an array of optical input ports and detection ports located in a selected geometrical pattern to provide a multiplicity of photon migration paths inside an examined region of the tissue;

placing said optical module on the exterior of the head of the subject;

introducing visible or infrared light from at least one said optical input port into an examined tissue region and receiving photons of light that have migrated in the examined tissue region to at least one of said detection ports;

detecting said received photons by at least one optical detector optically coupled to said least one said detection port;

controlling said introducing and detecting steps to collect optical data corresponding to photons of light that have migrated between selected input and detection ports;

processing said optical data to form at least two data sets, a first of said data sets representing blood volume in the examined tissue region and a second of said data sets representing blood oxygenation in the examined tissue region; and

correlating said first and second data sets to detect abnormal tissue in the examined tissue region.